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(54) IMPROVEMENTS IN AND RELATING TO  
RADIO RECEIVING SYSTEMS

(71) We, RACAL COMMUNICATIONS LIMITED, a British Company, of Western Road, Bracknell, Berkshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 The invention relates to radio receiving systems, and more particularly to diversity receiving systems in which two receivers are used, each arranged to receive signals whose fading characteristics are assumed to be different. In such systems, the output of the two receivers can be combined to produce a composite output signal, or one or other of the two receivers can be selected at any given time to feed the output. The aim in each case is to produce a resultant output with reduced fading characteristics.

According to the invention, there is provided a system responsive to the output signals of two radio receivers, in which only one or other of the two receiver outputs may be held connected to the system output at any given time, the selection of the particular receiver output to be so connected being achieved automatically according to a predetermined criterion, one of the receiver outputs, when the criterion becomes such that it is to be selected, becoming connected to the system output when its instantaneous audio output signal is passing through zero in a predetermined direction and the other of the receiver output previously becoming disconnected from the system output when its instantaneous audio output signal is passing through zero in the predetermined direction.

According to the invention, there is also provided a system responsive to the output signals of two radio receivers, comprising first input means for receiving the audio

output signal of the first radio receiver, second input means for receiving the audio output signal of the second radio receiver, switching means for connecting one or other of the two input means to output means, comparing means for comparing the AGC signals of the two receivers and responsive to a predetermined change in relationship between the magnitudes of the two AGC signals compared to condition the switching means to disconnect the one of the input means which is connected to the output means and to connect the other input means to the output means, and zero crossing detecting means for detecting the instants when the audio input signals to the two input means cross zero in the same predetermined direction whereby to cause the switching means to first disconnect the said one input means at the instant when the audio input signal to that input means crosses zero in the said direction and to connect the said other input means to the output means when the audio input signal to that input means next crosses zero in the said predetermined direction.

According to the invention, there is further provided a method of controlling the connection of either one of two radio receivers to an output in a diversity receiving system, comprising the steps of selecting one other of the two receiver outputs according as to which of them has the higher AGC signal, monitoring the audio output signals of the two receivers to determine the respective instants at which the output levels of the two audio output signals pass through zero in a predetermined direction, disconnecting the non-selected receiver output from the system output at one of the respective instants, and connecting the selected receiver output to the system output at an immediately following one of the respective instants.

A radio receiving system embodying the invention will now be described, by way of example only, with reference to the drawing of the Provisional Specification which is a schematic circuit diagram of part of the system.

The system to be described incorporates two receivers operating in diversity, that is, they are both tuned to receive the same signal but their respective antennae are arranged to receive the signal from different directions with the aim of ensuring that at least one of the receivers will produce a strong output signal whatever the reception conditions are. The system therefore also incorporates circuitry for selecting the audio output of one or other of the two receivers, so as to produce the best output signal at any time.

The circuitry for selecting one or other of the two audio outputs will now be described.

As shown in the Figure of the Provisional Specification, the circuitry incorporates input terminals 2 for receiving the audio output of one receiver (Receiver A), input terminals 6 for receiving the audio output of the second receiver (Receiver B), and output terminals 9 at which is produced the audio output of Receiver A or Receiver B according to which of these receivers is selected by the circuitry. Terminals 2 are connected across the primary winding of a transformer 3 whose secondary winding is connected, via a channel A incorporating lines A1 and A2 and a switch unit 4, across the primary winding of an output transformer 5 feeding the terminals 9.

Similarly, the input terminals 6 are connected across the primary winding of a further input transformer 7 whose secondary winding is connected, via a channel B incorporating lines B1 and B2 and a switch unit 8, across the primary winding of the output transformer 5.

In order to perform the selection process, the circuitry incorporates a comparing circuit 16 for comparing the magnitudes of the AGC signals of the two receivers, and the circuit 16 therefore has a terminal 18 at which is received the AGC signal of Receiver A and a terminal 20 at which is received the AGC signal of Receiver B.

The comparing circuit 16 comprises two NPN transistors 22 and 24 connected in a long-tailed pair configuration, through resistors 26 and 27, between a +12 volts line 28 and a zero volt line 30. If the AGC signal of Receiver A is greater than that of Receiver B, then transistor 22 is switched on and transistor 24 is switched off, and a positive or TRUE signal is therefore fed to a line 32 via a resistor 34 and a binary

amplifier unit 36 which ensures an abrupt switching action.

If the AGC signal of Receiver B is greater than that of Receiver A, then transistor 24 is rendered conductive and transistor 22 is switched off, and under these conditions a low or substantially zero volt FALSE signal is produced on the line 32.

The signal on the line 32 controls the states of two flip-flop units 38 and 40 in a manner to be described.

The flip-flop units 38 and 40 in turn control the switch units 4 and 8 so as to determine whether it is the audio output of the Receiver A or that of Receiver B which is fed to the output transformer 5.

Switch unit 4 comprises field effect transistors 42A and 44A whose source-drain paths are connected in series with the respective lines of channel A. The gate electrode of each FET is connected to the same channel line through a respective resistor 46A, 48A. The conduction of the FETs is controlled by the flip-flop 38 via a control line 50A which is connected to the gate electrode of the two FETs by respective diodes 52A and 54A.

The switch unit 8 for the channel B is similar to the switch unit 4, and corresponding items are similarly referenced save for the use of the suffix "B" instead of "A". The control line 50B for the switch unit 8 is connected to the flip-flop 40.

In order to supply power for the FETs of the two switch units, a power unit 60 is provided comprising a transistor 62 which is controlled by means of a potential divider network incorporating a zener diode 64 and a resistor 66 so as to produce a substantially constant d.c. output voltage across a capacitor 68. This voltage is connected to centre taps on the secondary windings of the transformers 3 and 7 and on the primary winding of the transformer 5, as shown by the letters X.

The channel A also incorporates a zero crossing detector circuit 70A. This comprises two NPN transistors 72A and 74A connected in a long-tailed pair configuration between the 12 volt line 28 and the zero volt line 30 via resistors 76A and 78A. When the audio signal in the channel A is such that the base of transistor 74A is passing through zero in a positive direction, and correspondingly the base of transistor 72A is passing through zero in the negative direction, transistor 74A is switched conductive and transistor 72A is switched off. The resultant negative-going signal at the collector of transistor 74A switches on a PNP transistor 80A which is connected in series between the lines 28 and 30 via a resistor 82A. The resultant signal is applied via an amplifier unit 84A and a feedback resistor 86A to the flip-flop

38. The amplifier unit 84A and the resistor 86A ensure a very rapid switching action. Therefore, whenever the unit 70A detects that the audio output in channel A is crossing zero in such a direction that its line A1 is becoming positive and its line A2 is becoming negative, it feeds a positive-going control signal to the flip-flop 38. When the signal in channel A is crossing zero in the opposite direction, no such control signal is produced.

Channel B also incorporates a similar zero-crossing detector circuit 70B which is similar in construction and operation to the detector circuit 70A, and corresponding items in it are similarly referenced save for the use of the suffix "B" instead of "A". The detector unit 70B is arranged to feed a positive control signal to a line 88B and thence to the flip-flop 40 when the audio output in channel B crosses zero in such a direction that the line B1 is becoming positive and the line B2 negative. When the signal in channel B changes in the opposite direction; no such control signal is produced.

The operation of the complete circuitry will now be described.

If the AGC signal from receiver A, at terminal 18, is more positive than the AGC signal from Receiver B on terminal 20, then a positive or TRUE signal exists on line 32. This conditions the flip-flop 38 to the "1" state. When the detector unit 70B next detects the audio signal in channel B as crossing zero in the direction such that line B1 is becoming positive, it produces a positive control signal on the line 88B which sets the flip-flop 40 into the "1" state. In this condition, the flip-flop produces a "0" output at its terminal Q. This signal is applied via the line 50B and biases on the diodes across the FET's 42B and 44B and the latter are therefore switched off, and channel B is therefore disconnected from the output transformer 5. After a slight delay, the output of terminal Q of the flip-flop 40, applied to the terminal R of flip-flop 38, RESETS that flip-flop into the "1" state. In that state its terminal Q produces a "1" output. The positive or "1" level on line 50A therefore biases diodes 52A and 52B off, switching FET's 42A and 42B on, and channel A is therefore connected to the output transformer 5. Since the flip-flop 40 is held "set" from the terminal Q of flip-flop 38, any control signal produced on line 88B will have no effect.

Therefore, in the condition existing, that is, with the AGC output of Receiver A greater than the AGC output of Receiver B, the circuitry selects Receiver A to feed the output after disconnecting Receiver B from the output.

When the comparator 16 detects that the AGC signal from Receiver B has become greater than that from Receiver A, it produces a zero volt or FALSE signal on line 32. This conditions the flip-flops to be switched into the "0" state, though neither yet switches into this state. When the zero crossing detector 70A next detects the audio signal in channel A as crossing the zero in the direction such that line A1 is becoming positive, the resultant control signal on line 88A clocks the flip-flop 38 into the "0" state. The resultant "0" signal on its terminal Q is applied to the switch unit 4 via the line 50A and switches off the FETs 42A and 44A. Channel A is therefore disconnected from the output transformer 5. At the same time, the "0" signal at terminal Q removes the "SET" signal from the terminal S of flip-flop 40.

When the zero crossing detector 70B next detects the audio signal in channel B as crossing the zero in the direction such that line B1 is becoming positive, the resultant control signal on line 88B therefore clocks the flip-flop 40 into the "0" state. The resultant "1" signal on its terminal Q is applied to the switch unit 8 via the line 50B and switches on the FET's 42B and 44B. It is also applied to the RESET terminal R of flip-flop 38 and locks that flip-flop in the "0" state.

The audio output of Receiver B has therefore been selected, and Receiver A has been disconnected. The system remains in this condition until the AGC output from Receiver A again exceeds that from Receiver B, whereupon a transition takes place between the two receivers, with Receiver B being disconnected first, and Receiver A being thereafter connected in its place to feed the output transformer 5.

The binary amplifier units 84A and 84B and associated resistors provide a hysteresis action to ensure at least a minimum switching speed on lines 88A and 88B. A similar hysteresis action is provided by the binary amplifier unit 36 and the associated resistors, and prevents hunting of the output in the event of the two AGC signals being very similar or of transients in the AGC signals.

With the circuitry described, it will be apparent that the selection between one receiver and the other involves a short period (which can be up to one complete audio cycle) when neither receiver is feeding the output. It is found that this gap in output is substantially undetectable, particularly with speech signals. The arrangement enables switching between one receiver and the other to take place at a zero signal level, and thus avoids transient signals which may occur in a system in which switching takes place between two receivers

irrespective of the levels of their audio outputs; such transients may cause output noise, "clicks" and the like.

The system disclosed is particularly suitable for true SSB operation, since with such operation, the audio output phase varies directly with the radio frequency signal phase, and the audio output from the two receivers could have any amount of phase difference. Should the phase difference be  $180^\circ$  and the two levels substantially equal, then straightforward additive combination of the two audio outputs would produce no final output at all.

#### 15 WHAT WE CLAIM IS:—

1. A system responsive to the output signals of two radio receivers, in which only one or other of the two receiver outputs may be held connected to the system output at any given time, the selection of the particular receiver output to be so connected being achieved automatically according to a predetermined criterion, one of the receiver outputs, when the criterion becomes such that it is to be selected, becoming connected to the system output when its instantaneous audio output signal is passing through zero in a predetermined direction and the other of the receiver outputs previously becoming disconnected from the system output when its instantaneous audio output signal is passing through zero in the predetermined direction.

2. A system according to claim 1, in which the said predetermined criterion is the relative magnitudes of the AGC signals of the two receivers.

3. A system responsive to the output signals of two radio receivers, comprising first input means for receiving the audio output signal of the first radio receiver, second input means for receiving the audio output signal of the second radio receiver, switching means for connecting one or other of the two input means to output means comparing means for comparing the AGC signals of the two receivers and responsive to a predetermined change in relationship between the magnitudes of the two AGC signals compared to condition the switching means to disconnect the one of the input means which is connected to the output means and to connect the other input means to the output means, and zero crossing detecting means for detecting the instants when the audio input signals to the two input means cross zero in the same predetermined direction whereby to cause the switching means to first disconnect the said one input means at the instant when the audio input signal to that input means crosses zero in the said direction and to connect the said other input means to the output means when the audio

input signal to that input means next crosses zero in the said predetermined direction.

4. A system according to claim 3, in which the comparing means is operative to condition the switching means to connect the first input means to the output means when the AGC signal of the first radio receiver is greater than that of the second radio receiver, and to connect the second input means to the output means when the AGC signal of the second radio receiver is greater than that of the first radio receiver.

5. A system according to claim 4, in which the comparing means incorporates means providing hysteresis in its response to one of the AGC signals exceeding the other, whereby to inhibit response of the comparing means to rapid changes in the relative magnitudes of the AGC signals.

6. A system according to any one of claims 3 to 5, in which the switching means comprises a first pair of field effect transistors connected between the first input means and the output means, and a second pair of field effect transistors connected between the second input means and the output means.

7. A system according to any one of claims 3 to 5, in which: the switching means incorporates first electronic switching means having a first state in which it connects the first input means to the output means and a second state in which it disconnects the first input means from the output means, a first flip-flop circuit having a first state and a second state for correspondingly setting the first electronic switching means into its said first or second state; second electronic switching means having a first state in which it connects the second input means to the output means, and a second state in which it disconnects the second input means from the output means, and a second flip-flop circuit having a first state and second state for correspondingly setting the second electronic switching means into its said first or second state; the comparing means comprises means operative to simultaneously condition the first flip-flop into the first state and the second flip-flop into its second state, or to simultaneously condition the first flip-flop into the second state and the second flip-flop into the first state, in dependence on the direction of the said predetermined change in the relationship between the magnitudes of the two AGC signals compared; the zero crossing detecting means comprises first means responsive to the audio signal applied to the first input means crossing zero in the said predetermined direction to clock the first flip-flop into the state in which it is con-

- ditioned, and second means responsive to the audio signal applied to the second input means crossing zero in the said predetermined direction to clock the second 25 flip-flop into the state in which it has been conditioned; means are provided which interconnect the two flip-flops such that the first flip-flop cannot change from its second to its first state until the second 30 flip-flop has first changed from its first to its second state, and the second flip-flop cannot change from its second to its first state until the first flip-flop has first changed from its first to its second state.
- 15 8. A method of controlling the connection of either one of two radio receivers to an output in a diversity receiving system, comprising the steps of selecting one or other of the two receiver outputs 20 according as to which of them has the higher AGC signal, monitoring the audio output signals of the two receivers to determine the respective instants at which the output levels of the two audio output signals pass through zero in a predetermined direction, disconnecting the non-selected receiver output from the system 25 output at one of the respective instants, and connecting the selected receiver output to the system output at an immediately 30 following one of the respective instants.
9. A system responsive to two radio receivers in a diversity receiving system, substantially as described with reference to the drawing of the Provisional Specification. 35
10. A method of controlling the connection of either one of two radio receivers to an output in a diversity receiving system, substantially as described with reference to the drawing of the Provisional 40 Specification.
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